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ABSTRACT

The purpose of the project was to develop computer games that could be used by students in grades 1-4 as part of their mathematics instruction. Eight games were developed, covering a wide variety of mathematical topics, including number/numeration, computation, geometry, measurement, statistics, and probability. The games were field tested in 20 K-5 classrooms. At each of three different schools a computer was placed in one classroom at a time for approximately four weeks. In each classroom the computer was used as a learning center. Records of student performance in the games were kept and, at the end of the four weeks, students were surveyed about their feelings about using the games and the teacher was interviewed. As a result of feedback from students and teachers, a number of revisions were made in the games. The field testing clearly indicated that instructional games can provide an easy, low-stress, enjoyable introduction to microcomputers for both students and teachers. The students enjoyed and learned from playing the games. (Author)

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FINAL PROJECT REPORT
NSF FORM 98A

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PART I - PROJECT IDENTIFICATION INFORMATION

1. Institution and Address	2. NSF Program	3. NSF Award Number
Wittenberg University Springfield, Ohio 45501	Using Information Technology - NSF/NIE	SED8012268
	4. Award Period: From 7/1/80 To 12/31/82	5. Cumulative Award Amount: $25,048

6. Project Title

The Use of Microcomputers for Mathematics Instruction in Grades 1-4

PART II SUMMARY OF COMPLETED PROJECT *(FOR PUBLIC USE)*

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The games were field tested in 20 K-5 classrooms. At each of three different schools a computer was placed in one classroom at a time for approximately four weeks. In each classroom the computer was used as a learning center. Records of student performance in the games were kept and, at the end of the four weeks, students were surveyed about their feelings about using the games and the teacher was interviewed. As a result of feedback from students and teachers, a number of revisions were made in the games.

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PART III - TECHNICAL INFORMATION *(FOR PROGRAM MANAGEMENT USES)*

1. ITEM *(Check appropriate blocks)*	NONE	ATTACHED	PREVIOUSLY FURNISHED	TO BE FURNISHED SEPARATELY TO PROGRAM	
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a. Abstracts of Theses	X				
b. Publication Citations		X			
c. Data on Scientific Collaborators		X			
d. Information on Inventions	X				
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2. Principal Investigator/Project Director Name *(Typed)*	3. Principal Investigator/Project Director Signature	4. Date
Dr. William H. Kraus	William H. Kraus	11/10/83

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IIIb. Publication Citations

The Computer as a Learning Center has been tentatively accepted for publication in the 1984 Yearbook of the National Council of Teachers of Mathematics. (copy attached.)

A paper on developing instructional computer games will probably be submitted to Creative Computing magazine.

IIIc. Scientific Collaborators

Dr. John G. Harvey, Professor of Mathematics and Curriculum and Instruction at the University of Wisconsin - Madison, and Dr. J. Gilbert Ware, Assistant Professor of Education at Wittenberg University, served as consultants to the project.

Presentations on the project were, or will be, made at the following conferences:

The National Council of Teachers of Mathematics Annual Meeting, Toronto, April 16-19, 1982.

The Annual Indiana Conference on Instructional Computing, Muncie, October 2, 1982.

The Ohio Education Department Annual Computer Fair, Columbus, December 6-7, 1982.

The National Council of Teachers of Mathematics Great Falls Conference, Great Falls, Montana, March 10-12, 1983.

12/82

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Project Overview

The purpose of the project was to develop computer games that could be used by students in grades 1-4 as part of their mathematics instruction. During the 1980-81 academic year and the summer of 1981 eight instructional games were developed; the content of the games ranges across the ten basic skill areas defined in the National Council of Supervisors of Mathematics "Position Statement on Basic Skills".

1. Saucer - counting; readiness for addition and subtraction. Grades K-1.

2. Faces - counting and base ten numeration. Grades K-4.

3. The Jar Game - problem solving; readiness for probability and for ordering fractions. Grades K-6.

4. Chaos - classification of geometric figures by attribute; concepts of left, right, up, down. Grades 2-6.

5. Fish Chase - drill in basic addition and multiplication facts. Grades 2-6.

6. Patterns - problem solving; construction of geometric figures; spatial visualization. Grades 2-4.

7. Golf - angle and length estimation. Grades 4-8.

8. Compu-Bar - problem solving; reading bar graphs; constructing simple arithmetic expressions. Grades 4-8.

The games are menu-driven and include a management system that keeps records of student performance in a disk file accessible to the teacher. (The games were initially implemented on an Atari 800 with 32K of memory and a single disk drive.)

During the 1981-82 academic year the programs were field-tested in 20 classrooms ranging from kindergarten through fifth grade. Three schools were selected to represent different educational philosophies and different socio-economic levels in the field testing. In fall of 1981, inservice programs were held at the three schools. At each school a computer was then placed in one classroom at a time for approximately four weeks.

Conclusions

The primary purpose of the field testing was to find ways to revise the games to make them more effective in providing instruction in mathematics.

Because of feedback from students and teachers, numerous modifications were made in the games. These ranged from minor modifications such as color or format changes to make the screen display more effective to modifications such as adding an intermediate level of difficulty to Faces or changing the level of difficulty of the math content of Chaos to better match the level of difficulty of the mechanics of the game.

However, in addition to facilitating improvement in the games, the field testing provided considerable informal evidence on the use of instructional computer games in the classroom. The clearest conclusion that can be drawn from the field testing is that instructional computer games can provide an easy, low-stress, enjoyable introduction to microcomputers for both students and teachers. Very few of the teachers in the study had had any prior experience with microcomputers, and most were somewhat apprehensive about using a computer in their classroom, but, without exception, when they saw how quickly their students learned how to use the computers and how much they seemed to enjoy and learn from the games, the teachers enjoyed the experience and expressed a desire to use the computer in the future. (All that needs to be done now is to determine where to get enough computers to satisfy the needs of all the teachers!)

It also seems clear that, at least in the lower elementary grades, the computer belongs in the classroom, where the teacher can depend on its being available throughout the day. The microcomputer is very useful as a learning center to supplement regular instruction. In particular, in some of the self-contained primary grade classrooms, the computer was used almost constantly from fifteen minutes before the school day began to half an hour after it ended.

Time-on-task is critical in the classroom; the games were written so that students could sit down at the computer and be actively involved in a game in less than one minute. The students could also stop any game almost immediately when it was time for them to do something else in the class. The use of a disk drive instead of a cassette recorder is a significant factor in increasing time-on-task.

Teachers that used the management system found it useful in keeping track of student progress and in guiding subsequent student work, but not all teachers used the management system. It will take time for teachers to more fully utilize the capabilities of the computer. Courseware will need to be developed to help teachers integrate use of the computer with other instruction.

Some observations of student performance in specific games were revealing. The Jar Game, a probability game, was successfully played by kindergartners, indicating that, if we find the appropriate format, we can lay the groundwork for some of the more sophisticated mathematical concepts at an early age. The poor performance in the 0-19 and 0-49 levels of Faces, a number/numeration game, indicates a lack of understanding of base ten numeration (they can point to the tens' place, but they don't really know what it means). The success that selected second and third grade students had in Golf and Compubar indicates that such games have potential for use in programs for the gifted.

Summaries of much of the data collected during the field testing are attached. Of particular interest is the summary of the teacher interviews.

Publication of the Games

Wittenberg University has contracted with Milliken Publishing Company (1100 Research Boulevard, St. Louis, Missouri 63132) to publish the programs.

The programs are being published in both a home package and a school package; the school package includes offline, supplemental courseware. The programs are currently available in 16K cassette and 32K disk versions for the Atari 400/800 and in a disk version for the Apple II. There are plans to convert the programs to run on several other microcomputers.

Milliken has over 22 years experience in publishing teaching aids and over four years experience in publishing microcomputer courseware. Their editorial staff has done an exemplary job of maintaining (and even improving) the pedagogical value of the games.

Teacher Interviews

Each of the 20 teachers who participated in the field testing was interviewed after they had had the computer in their classroom. The same 10 questions were asked in each interview.

Did you find enough time to use the computer? Would you be able to fit the computer into your normal classroom routine? Only two teachers, both teaching fifth grade, answered "no" to these two questions. Although they were able to make use of the computer, they did not feel they were able to make enough use of it to make it cost effective. The 18 teachers who answered "yes" indicated a variety of ways to find time, including during reading groups, when students had finished other work, during indoor recess, and during small group instruction time. The games were occasionally used in whole group instruction. Several teachers mentioned using the games as a reward. Setting up a formal schedule for computer use, to ensure that all students had opportunities to play the games, was mentioned by many of the teachers.

Did you find the games easy or difficult to use? What problems, other than math content, did students encounter in using the games? All of the teachers indicated the computer was easy to use. This was one of the most welcome results, since the majority of the teachers had initially expressed some apprehension about how difficult using the computer might be. Seventeen of the teachers indicated their students had encountered no problems in using the games. The others indicated only minor problems with specific games (which led to modification of those games).

How appropriate was the level of the math content of the games for your students? Answers to this question helped clarify the appropriate grade levels for the various games.

Were the games too short/too long, too slow/too fast? All the games except Saucer seemed to be of appropriate length and speed. Two teachers indicated that Saucer was too slow, and consequently it was speeded up. Several teachers indicated that students tended to pick the slower/easier levels of multilevel games; differential rewards helped lessen this to some extent.

Did you use the sound without headphones? If so, was it distracting? Headphones were supplied with the computer system, but eighteen of the twenty teachers did not have their students use them. Of these eighteen, only one indicated that the sound was distracting after the first day or two. (The volume could be controlled.)

Do you have any comments or suggestions that might be useful to other teachers using the games? The most common comments were (a) don't be afraid of the computer, (b) introducing each game to the class as a whole is the most efficient way to have the children learn the rules of the games, (c) set up rules for computer use, and (d) set up a schedule for computer use.

Do you have suggestions for improvements in the games? Do you have any suggestions for new games? There were many suggestions for minor modifications in the games that would facilitate their use in the classroom; many of these sugestions were incorporated into the games. Many suggestions for math content for additional games were given, including computation beyond basic facts, word problems, place value, telling time, money, fractions, use of the ruler, and map skills.

Although all but one of the teachers in the field testing were novices in computer use, no significant problems were encountered in the use of the games. In addition, many invaluable suggestions for improvements in the games came from these teachers, and I am truly appreciative of their contributions to the development of the games.

Basic Skills Survey

Prior to development of the games, teachers at the three schools that were to participate in the field testing were asked to complete a questionnaire. The survey was conducted to determine the teachers perceptions and needs in the 10 basic skill areas in mathematics defined in the NCSM position statement on basic skills. Responses were received from 23 of the 30 teachers at the schools. The questionnaire was prefaced by some excerpts from the NCSM position statement. Thirteen of the 14 questions asked in the survey are reproduced on the following page. The remaining question (#13) asked for specific instructional problems and needs in each of the 10 basic skill areas.

The results of the survey are summarized in the table on a following page. The results are not unlike results of other recent surveys. Computation and problem solving are seen as most important and occupy the greatest amount of instructional time for most teachers (comments on the questionnaires indicate clearly that most teachers equate "problem solving" and "word problems"). Interestingly, these two areas were the areas most teachers indicated (a) they felt best prepared to teach and (b) they would like assistance with. Probability and computer literacy were seen as the least important basic skill areas.

Although the survey was useful in providing a picture of the teachers perceptions of basic skills, it proved not to be useful in identifying appropriate content for the games. It did, however, ensure that most of the teachers who would be involved in the field testing were aware of the NCSM position statement that provided the mathematical content framework for the development of the games.

1. Which of the ten basic skill areas do you feel are most important in grades K-8?

2. Which of the ten basic skill areas do you feel are least important in grades K-8?

3. Which of the ten basic skill areas do you feel are most important at your grade level?

4. Which of the ten basic skill areas do you feel are least important at your grade level?

5. Which of the ten basic skill areas do you spend the most time on in your class?

6. Which of the ten basic skill areas do you spend more than two weeks of class time on?

7. Which of the ten basic skill areas do you spend the least time on in your class?

8. Which of the ten basic skill areas do you spend less than 1 week of class time on?

9. Which of the ten basic skill areas do you feel best prepared to teach?

10. Which of the ten basic skill areas do you feel least prepared to teach?

11. Which of the ten basic skill areas are most difficult to teach at your grade level and why?

12. Which of the ten basic skill areas that you currently spend less than 1 week of class time on would you like to spend more time on and why are you currently unable to do so?

13. Which two or three of the basic skill areas would you most like to have assistance in?

Summary of Basic Skills Survey Responses (N=23)

	1 Problem Solving	2 Application	3 Reasonable Results	4 Estimation	5 Computation	6 Geometry	7 Measurement	8 Graphs	9 Probability	10 Computer Literacy
1. most important K-8	22	17	13	6	16	8	11	5	0	3
2. least important K-8	0	1	1	6	1	4	1	6	17	14
3. most important 1-4	17	15	7	5	18	7	9	4	0	0
4. least important 1-4	0	1	1	9	1	7	2	10	17	12
5. spend most time on	17	11	4	4	19	5	6	1	0	0
6. spend more than 2 weeks	20	12	6	6	19	8	10	6	0	0
7. spend least time on	0	2	1	6	2	5	2	10	17	19
8. spend less than 1 week	0	3	1	7	0	5	5	8	14	15
9. best prepared to teach	19	13	13	10	20	11	11	10	2	1
10. least prepared to teach	0	2	1	0	0	4	6	4	11	19
11. most difficult to teach	6	2	1	4	2	2	4	5	12	10
12. like to spend more time on	2	1	1	2	0	2	5	2	4	8
14. like assistance with	8	5	1	1	11	1	5	3	2	4

Game Performance Data

For each game, data is stored on student performance on the mathematics content in the game, so that the teacher may examine these data to see what each student has done and how well the student has done. These data are summarized in the following tables for 11 of the classrooms used in the study.

Great caution must be used in interpreting these data, because the studies were done informally in natural classroom settings. The abilities of the students that played specific games and the differing degrees of assistance provided by the teachers cannot be determined from the tables. For example, in several of the primary grades the teachers selected their best students to play Golf and Compubar and gave them some initial instruction in the mathematics involved in the games; in the fourth and fifth grades a cross-section of the students played these games without significant extra instruction on the mathematics content.

For each game the N is the number of different students that played the game more than once. The first time a student played a game was not included in the calculation of the mean, to lessen the effect that learning the rules of the game would have on performance in the game.

For Golf, the mean is the average number of strokes per hole. For The Jar Game, the mean is the percentage of correct choices. For Fish Chase, the mean is the number correct answers out of a possible 20. For Patterns, the mean is the percentage of correctly matched patterns. For Faces, the mean is the number of correct answers before an answer was missed. For Chaos, the mean is the number of correct matches before one was missed or time ran out. Two versions of Chaos were used in the studies, and this accounts for the large differences in means between grade levels. For Saucer, the mean is the percentage of correct answers. For Compubar, the mean is the percentage of correct answers.

GRADE 1

NAME	N	MEAN	S.D.
GOLF	7	5.4	1.7
BAR	20	93	18.9
ISH ADD/EASY/SLOW	40	7.2	5.1
ISH MUL/EASY/SLOW	0	0	0
ISH ADD/HARD/SLOW	2	3	1
ISH MUL/HARD/SLOW	0	0	0
ISH ADD/EASY/FAST	3	7.3	2.5
ISH MUL/EASY/FAST	0	0	0
ISH ADD/HARD/FAST	0	0	0
ISH MUL/HARD/FAST	1	2	0
ATTERNS	4	56.1	23.4
ACES 0-5	10	18.9	13.2
ACES 0-9	6	4.7	3.2
ACES 0-19	11	5.7	5.3
ACES 0-49	2	6.7	8
HAOS	21	55.4	74
AUCER 0-5	0	0	0
AUCER 0-10	7	84.4	32.4
OMPUBAR	8	42.9	29.8

GRADE 2

NAME	N	MEAN	S.D.
OLF	11	6.1	2.4
AR	38	88.4	20.9
ISH ADD/EASY/SLOW	46	10.7	6.5
ISH MUL/EASY/SLOW	1	4	0
ISH ADD/HARD/SLOW	0	0	0
ISH MUL/HARD/SLOW	0	0	0
ISH ADD/EASY/FAST	2	8	5.8
ISH MUL/EASY/FAST	0	0	0
ISH ADD/HARD/FAST	1	5.5	0.5
ISH MUL/HARD/FAST	0	0	0
ATTERNS	32	17.5	34.5
ACES 0-5	7	9.8	7.7
ACES 0-9	5	9.7	6.6
ACES 0-19	7	10.3	6.1
ACES 0-49	6	6.7	6.4
HAOS	37	8.7	10.9
AUCER 0-5	3	75	35.4
AUCER 0-10	12	88.9	9.7
OMPUBAR	8	21.2	31.8

GRADE 3

GAME	N	MEAN	S.D.
GOLF	9	3.8	1.2
JAR	3	92.9	17.5
FISH ADD/EASY/SLOW	17	14.2	5.8
FISH MUL/EASY/SLOW	13	6.3	3.9
FISH ADD/HARD/SLOW	3	6.1	3.4
FISH MUL/HARD/SLOW	0	0	0
FISH ADD/EASY/FAST	4	18	3.7
FISH MUL/EASY/FAST	0	0	0
FISH ADD/HARD/FAST	2	7.5	2.3
FISH MUL/HARD/FAST	0	0	0
PATTERNS	1	100	0
FACES 0-5	1	42.8	28.8
FACES 0-9	0	0	0
FACES 0-19	1	13	0
FACES 0-49	1	4	0
CHAOS	11	83.3	66.7
SAUCER 0-5	1	70	0
SAUCER 0-10	2	89	29.8
COMPUBAR	6	30.8	41.8

GRADE 4

GAME	N	MEAN	S.D.
GOLF	31	6.7	3
JAR	15	89.6	20.2
FISH ADD/EASY/SLOW	14	18.4	3.8
FISH MUL/EASY/SLOW	11	12.8	6.7
FISH ADD/HARD/SLOW	5	18.9	2.6
FISH MUL/HARD/SLOW	5	16.6	6.8
FISH ADD/EASY/FAST	1	10	0
FISH MUL/EASY/FAST	0	0	0
FISH ADD/HARD/FAST	0	0	0
FISH MUL/HARD/FAST	1	14	0
PATTERNS	16	27.5	43.2
FACES 0-5	1	3.5	1.5
FACES 0-9	5	6.3	5.4
FACES 0-19	8	6.5	7.4
FACES 0-49	2	7.5	3.5
CHAOS	30	11.4	12.2
SAUCER 0-5	1	0	0
SAUCER 0-10	3	66.7	47.1
COMPUBAR	21	27.8	27.7

GRADE 5

GAME	N	MEAN	S.D.
GOLF	15	5.8	2.
JAR	25	88.2	22.8
FISH ADD/EASY/SLOW	7	12.3	6.8
FISH MUL/EASY/SLOW	6	17.8	3.9
FISH ADD/HARD/SLOW	0	0	0
FISH MUL/HARD/SLOW	3	13	5.4
FISH ADD/EASY/FAST	1	16.6	1.9
FISH MUL/EASY/FAST	1	20	0
FISH ADD/HARD/FAST	7	4.6	3.1
FISH MUL/HARD/FAST	13	9.6	4.1
PATTERNS	1	0	0
FACES 0-5	5	38.4	21.1
FACES 0-9	2	4.6	6.3
FACES 0-19	2	2.2	1.9
FACES 0-49	11	12.7	7.7
CHAOS	57	15.1	17.3
SAUCER 0-5	2	61.9	44.2
SAUCER 0-10	2	45	45
COMPUBAR	29	54.4	49

Golf/Compubar Study

Most of the field testing of the programs was done informally, to allow the teachers to use the games as they wanted to, and then to get direct feedback from the teachers on how the games could be best used in the classroom and on how the games could be improved. However, one formal experiment was conducted to study the effects of the two most complex games, Golf and Compubar.

A class of 20 grade four students, a class of 24 fifth grade students, and a class of 21 fifth grade students were used in the study. Each class was divided randomly into two groups; the students in one group played Golf exclusively over a period of two weeks, the students in the other group played Compubar exclusively during that same period. To facilitate scheduling the use of the single computer in each classroom, pairs of students played the games, with each pair playing the games for a total of approximately one hour, spread out over 2-4 sessions. According to the teachers, the students had had previous experience with bar graphs, arithmetic expressions, and linear measurement, but little or no experience with angle measurement. No direct instruction on these topics was provided during the two weeks of the study.

At the end of the two weeks, all students were given two tests: (a) a 10-question test on reading bar graphs and constructing arithmetic expressions and (b) a 10-question test on estimating the size of angles and the length of lines. Thus two studies were conducted simultaneously, a study of the effects of playing Compubar, with the Golf group serving as the control group, and a study of the effects of playing Golf, with the Compubar group serving as the control group.

The results of the two studies are summarized in the tables on the following page. Although in both cases the experimental group scored higher on the posttest than the control group, this difference was not statistically significant. It may be that to be effective (a) the games must be played more frequently or for longer periods at a time or (b) the games must be combined with direct instruction on the mathematical content (neither of these is a particularly surprising hypothesis).

Now that the initial development stage for the games has been completed, studies to determine the most effective classroom applications of the games would certainly be appropriate.

t - test for Bar Graph/Arithmetic Expression Test

Group	N	Mean	S.D.
experimental	34	7.6	2.4
control	39	6.8	2.2

t: -1.38

p: 0.17

t - test for Angle/Linear Estimation Test

Group	N	Mean	S.D.
experimental	39	3.3	2.3
control	34	3.1	2.5

t: 0.44

p: 0.73

Survey of Students

In the first 14 classrooms used in the field testing, the students were asked to complete a survey about how they felt about using the games; they had been using the games for approximately one month when the survey was administered. For each of the eight games the survey asked students to indicate how they felt about the game by selecting one of the following choices: (a) I didn't like it, (b) It was OK, (c) I liked it, or (d) I liked it a lot. This was followed by eight statements about the use of the games, and the students were asked to indicate if they (a) strongly disagreed, (b) disagreed, (c) agreed, or (d) strongly agreed with the statement. To simplify filling out the survey for the younger students the version of the survey used in the primary grades (1-3) was read to the students by their teacher and required them to mark frowning or smiling faces that corresponded to the choices listed above.

Results of the survey are summarized in the two tables on the following pages. It is clear that the students enjoyed using the games. The most liked games at both the primary and intermediate levels were The Jar Game and Chaos, and, understandably, the least liked games were the games in which the level of the mathematics content was not appropriate for the grade level (i.e., Golf and Compubar at the primary level and Saucer at the intermediate level). The responses to the second half of the survey indicate that students not only enjoyed playing the games, but also felt that they had played the games well and that they had learned about mathematics from the games.

How did you feel about the game?

I didn't like it.	It was OK.	I like it.	I liked it a lot.
1	2	3	4

	Grades 1-3			Grades 4-5		
Game	N	Mean	S.D.	N	Mean	S.D.
Golf	21	2.8	1.0	84	3.2	0.9
Jar Game	59	3.6	0.7	121	3.4	0.8
Fish Chase	85	3.2	0.9	157	3.2	0.9
Patterns	64	3.2	0.9	57	2.8	1.1
Faces	87	3.3	0.9	74	3.1	1.0
Chaos	82	3.5	0.8	108	3.4	1.0
Saucer	63	3.3	0.9	41	2.4	1.1
Compubar	20	2.9	1.1	122	2.9	1.1

How do you feel about these statements?

strongly agree	disagree	agree	strongly disagree
1	2	3	4

	Grades 1-3			Grades 4-5		
	N	Mean	S.D.	N	Mean	S.D.
I like using the computer.	89	4.0	0.2	170	3.8	0.5
Computer games are fun.	89	3.7	0.5	171	3.7	0.5
Computer games help me learn math.	88	3.4	0.9	167	3.4	0.6
I played the games well.	89	3.7	0.6	169	3.2	0 6
I liked the color pictures on the TV screen.	89	3.7	0.7	171	3.3	0.7
I liked the sound.	88	3.7	0.6	171	3.4	0.7
I wish I had more time to play the games.	89	3.9	0.4	170	3.8	0.4
The computer teaches me about math.	88	3.5	0.9	167	3.3	0.7